XI. LEW 88516

Peridotite, 13.2 grams

Weathering A/B

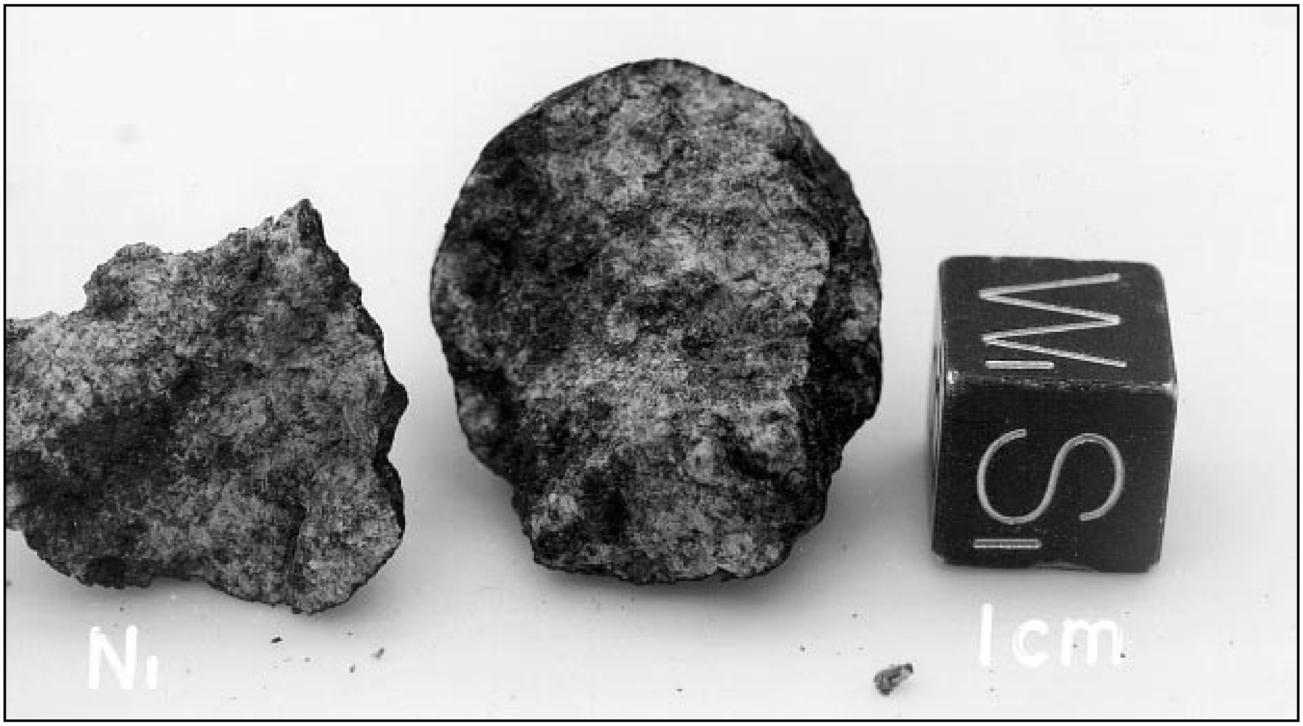

Figure XI-1. *Photograph of Martian meteorite LEW88516 after first break for processing. Cube is 1 cm for scale. (NASA # S91-37060)*

Introduction

Lewis Cliff sample LEW88516 is petrologically similar to ALHA77005 (Satterwhite and Mason, 1991; Treiman *et al.*, 1994) and Y793605 (Kojima *et al*., 1997). However, it is not paired, because it has a distinctly different terrestrial exposure age. Figure XI-1 shows LEW88516 as a small (2 cm), dark, rounded, meteorite with coarsely crystalline interior.

LEW88516 was a small nondescript meteorite that was not recognized as an achondrite until it was broken open. Hence, it waited 2 years to be processed in numerical order. According to Satterwhite and Mason (1991), LEW88516 had a *"pitted and mostly shiny fusion crust over 80 % of the surface."* Preliminary examination of the thin section showed about 50 % olivine (Fa_{33}), 35 % pyroxene, 8 % interstitial maskelynite (An_{53}) with about 5% brown glass. Grain size is about 2 - 3 mm.

Petrography

Harvey *et al*. (1993), Treiman *et al*. (1994) and Gleason *et al*. (1997) have given detailed petrologic descriptions of LEW88516 and report that it is similar to ALHA77005 (figure XI-2). This meteorite has three distinct textural regions: 1) poikilitic crystalline, 2) interstitial crystalline (or non-poikilitic) and, 3) glassy to partially crystalline veinlets. Delaney (1992), Lindstrom *et al*. (1992) and Harvey and McSween (1992) have also reported petrological descriptions of LEW88516.

In the poikilitic regions, mm-sized olivine crystals and 50 micron-sized chromite crystals are contained within, and completely surrounded by, pigeonite crystals with exsolution lamellae of augite. Maskelynite, whitlockite and sulfides are rare in the poikilitic regions.

The interstitial areas have a more typically basaltic texture with intergrown euhedral and subhedral olivine,

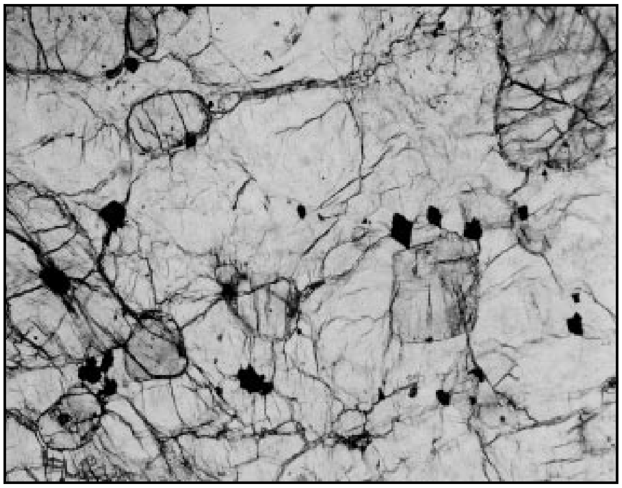

Figure XI-2. Photomicrograph of thin section of LEW88516,6. Euhderal chromite and rounded olivine crystals are poikilitically included in large orthopyroxene. Field of view is 2.2 mm.

pigeonite and chromite, with interstitial maskelynite, pigeonite, whitlockite, ilmenite and pyrrhotite.

The glass veinlets are the result of shock melting of the other lithologies (Harvey *et al.,* 1993).

Melt inclusions in large olivine grains were studied by Harvey *et al*. (1993) and used to calculate the composition of the parental melt - which was found to be similar to the calculated parental melt of other shergottites.

Mineral Mode

	Treiman *et al.* 1994	**Wadhwa** *et al.* 1994	**Gleason** *et al.* 1997
Olivine	45.9	50-59	57
Orthopyroxene	25.3		
Clinopyroxene	12	35	22
Plagioclase	7	8-5	16
Ca-phosphate	0.9	1.7	<1
chromite	0.8	0.7-2	3
Ilmenite	0.2		
Pyrrhotite	0.3		<1
Melt	7.7		

Mineral Chemistry

Olivine: Olivine is a major component of the poikilitic portion of LEW88516. It is compositionally zoned from Fo_{70} to Fo_{64}, averaging Fo_{67}. This is slightly more Fe-rich than the olivine in ALHA77005. In both LEW88516 and ALHA77005, the olivine has a distinct brown color apparently due to Fe^{+3} produced by "shock oxidation" (Ostertag *et al.,* 1984).

Pyroxene: Both low-Ca and high-Ca pyroxenes are present (figure XI-3). The large pyroxene oikiocrysts in the poikilitic portion are relatively homogeneous while the smaller pyroxenes in the non-poikilitic portion are zoned in composition. Harvey *et al*. (1993) have determined the REE and Ti, Al, Sc, Y, Zr, Cr and V contents of the different pyroxenes. Whereas the pyroxenes in LEW88516 are slightly more Fe rich, the trace element patterns are identical (see also Wadhwa *et al*., 1994 (figure IX-14).

Maskelynite: Maskelynite in LEW88516 has an average composition of An_{52} and a range from An_{24-58} (Treiman *et al*., 1994) and is reported to contain small "bubbles".

Chromite: Chromite is the most abundant accessory mineral in LEW88516. Chromite grains are commonly zoned or altered toward ulvöspinel compositions at their rims (Harvey *et al.,* 1993; Gleason *et al.,* 1997). Treiman *et al*. (1994) give the composition of 3 chromite grains and one grain that is a solid solution of titanomagnetite and chromite.

Ilmenite: Gleason *et al.* (1997) give the composition of ilmenite.

Kaersutite: Treiman (1998) gives the composition of "kaersutitic" amphiboles found in melt inclusions in pigeonite within LEW88516.

Whitlockite: Whitlockite occurs as a common accessory phase in the interstices of the non-poikilitic

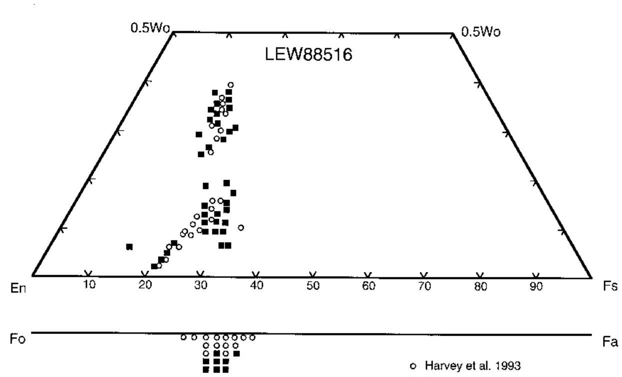

Figure XI-3. Composition diagram for pyroxene and olivine in LEW88516. Data are replotted from Harvey et al. (1993) and Treiman et al. (1994).

areas of LEW88516. Harvey *et al*. (1993) determined the REE content to be about 150X C1 chondrites. The REE pattern of the whitlockite is found to be very similar to that of the bulk rock, as was also the case for ALHA77005. Gleason *et al.* give the composition of whitlockite in LEW88516.

***Sulfides*:** Dreibus *et al.* (1992), Harvey *et al*. (1993) and Treiman *et al.* (1994) reported pyrrhotite in LEW88516 and Dreibus *et al.* determined that it contained 1.8 % Ni.

Whole-rock Composition

Dreibus *et al*. (1992), Treiman *et al*. (1994) and Gleason *et al.* (1997) found that the composition of LEW88516 was almost identical to that of ALHA77005 (figure XI-4). Ir was found to be low, in the range of the terrestrial upper mantle (Dreibus *et al.*, 1992). In addition to the data in table XI-1, Brandon *et al.* (1997) have reported Re (26.3 ppt) and Os (885 ppt) and the isotopic composition of Os.

Analyses by Trieman et al. (1994) and by Warren and Kallemeyn (1996) gave anomalous Ce.

Radiogenic Isotopes

Borg *et al.* (1997) reported the crystallization age, as determined by Rb-Sr, to be 183 ± 10 Ma with an initial $^{87}Sr/^{86}Sr$ of 0.710518 ± 60 (figure XI-6). Borg *et al*. (1998) reported an Sm-Nd isochron age of 166 ± 30 Ma (figure XI-8). This agrees roughly with the U-Pb systematics as determined by Chen and Wasserburg (1993) who found that there was a lead-loss event ~ 170 Ma.

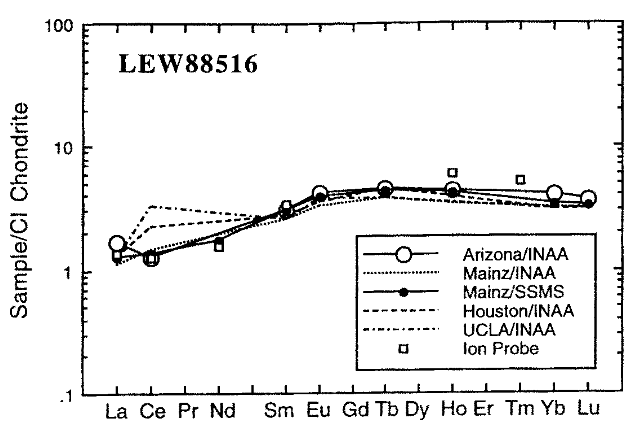

Figure XI-4. *Summary REE diagram from Gleason et al. (1997).*

Cosmogenic Isotopes and Exposure Ages

Nishiizumi *et al.* (1992) and Jull *et al.* (1994) give a terrestrial exposure age of 21 ± 1 thousand years.

Treiman *et al.* (1994) used their ^{21}Ne and the ^{10}Be activity of 16.6 dpm/kg from Nishiizumi *et al*. (1992) to calculate an exposure age of LEW88516 of 3.0 Ma. From cosmic-ray produced ^{3}He, ^{21}Ne and ^{38}Ar, Eugster *et al.* (1996) derived an exposure age for LEW88516 of 4.1 ± 0.4 Ma and concluded that LEW88516 was *"ejected from Mars simultaneously with the other lherzolitic shergottite ALHA77005 (3.4 Ma)."*

Other Isotopes

Ott and Lohr (1992), Bogard and Garrison (1993) and Becker and Pepin (1993) determined rare gas abundances in LEW88516. Becker and Pepin (1993) and Ott *et al*. (1996) determined that the noble gasses in a glass sample from LEW88516 were in the same ratio as those in EETA79001, but much less abundant (figure XI-5).

Clayton and Mayeda (1996) reported the oxygen isotope composition of LEW88516 (figure I-2.) verifying that it is Martian.

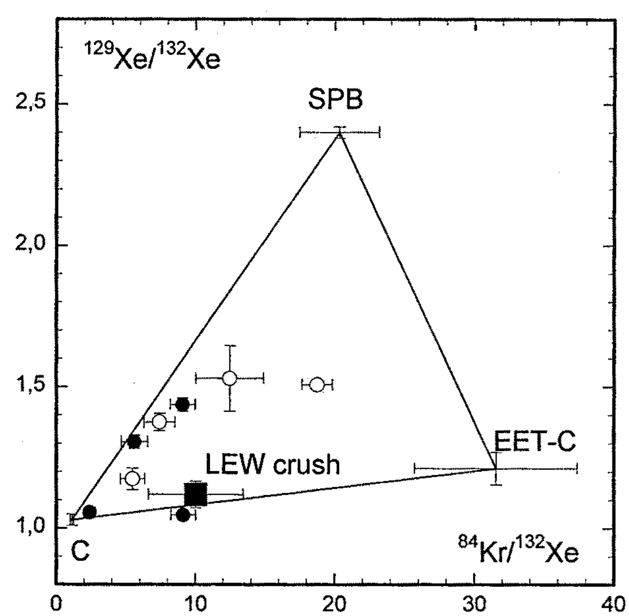

Figure XI-5*. Krypton and Xe in LEW88516 for several Martian meteorites as presented by Ott et al. (1996), Meteoritics* ***31****, 103. Triangle defined by Chassigny (C), Mars atmosphere (SPB) and EETA79001 crush components. Data for Shergotty and Zagami are open circles and data for LEW88516 are filled symbols.*

Table XI-1. Chemical composition of LEW88516.

	Dreibus92	Dreibus92	Treiman94a			Warren96						Gleason97	Gleason97
			,13a	,13b	,6								
weight			33 mg	39 mg	19 mg	glass-rich		glass-poor		powder			
SiO2 %	45.5 (a)					47.06						44.5*	43.0*
TiO2	0.42 (a)					0.4		0.26		0.32		0.36 (a)	0.45 (a)
Al2O3	2.99 (a)					2.362		1.23		2.93		3.45 (a)	3.86 (a)
FeO	19.49 (a)		19.5 (a)	19.3 (a)	23 (a)	18.27		16.47		18.91		20.9 (a)	20.3 (a)
MnO	0.47 (a)					0.47		0.48		0.48		0.51 (a)	0.51 (a)
CaO	4.06 (a)		4.3 (a)	4.4 (a)	3.7 (a)	4.925		4.757		4.114		4.25 (a)	4.54 (a)
MgO	25.66 (a)					23.87		23.71		25.5		23.7 (a)	24.9 (a)
Na2O	0.49 (a)		0.536 (a)	0.558 (a)	0.7 (a)	0.386		0.156		0.516		0.588 (a)	0.595 (a)
K2O	0.024 (a)		0.031 (a)	0.03 (a)	0.033 (a)	0.289		0.182		0.301		0.028 (a)	0.028 (a)
P2O3		0.39 (b)											
sum	**99.104**					**98.03**						**98.26**	**98.18**
Li ppm													
C	74 (a)												
F	27 (a)												
S	950 (a)												
Cl	29 (a)												
Sc	25.1 (a)		25.1 (a)	25.2 (a)	22.8 (a)	27.4 (a)		29.8 (a)		25.2 (a)		26.7 (a)	26.5 (a)
V	180 (a)					196 (a)		198 (a)		143 (a)		171 (a)	178 (a)
Cr	5672 (a)		5747 (a)	5816 (a)	5269 (a)	6900 (a)		8400 (a)		5800 (a)		6295 (a)	6568 (a)
Co	62.7 (a)		54.1 (c)	65.6 (a)	62.3 (c)	61.2 (a)		55.6 (a)		66.7 (a)		66.5 (a)	64.1 (a)
Ni	250 (a)		280 (a)	300 (a)	300 (a)	226 (a)	244 (c)	229 (a)	230 (c)	245 (a)	254 (c)	315 (a)	276 (a)
Cu	<80 (a)						(c)						
Zn	70 (a)		47.1 (c)		54.7 (c)	62 (a)	52 (c)	66 (a)	50 (c)	69 (a)	54 (c)	62.1 (a)	60.6 (a)
Ga	8.4 (a)					7.6 (a)		5.8 (a)		8.7 (a)		9.1 (a)	10.4 (a)
Ge							0.262 (c)		0.7 (c)		0.6 (c)		
As	<0.15 (a)					<0.54 (a)		<0.47 (a)		<0.93 (a)			
Se	<0.70 (a)		0.22 (c)		0.35 (c)	<0.73 (a)		<1.2 (a)		<0.64 (a)		0.35 (a)	0.44 (a)
Br	0.05 (a)												
Rb		0.83 (b)	0.174 (c)		0.199 (c)							1.41 (a)	0.97 (a)
Sr		14.7 (b)	30 (a)	20 (a)								14.3 (a)	17.7 (a)
Y		5.69 (b)											
Zr		17.2 (b)										12.4 (a)	9.6 (a)
Nb		0.51 (b)											
Mo													
Pd ppb													
Ag ppb			4.6 (c)		7.5 (c)								
Cd ppb			9.6 (c)		15.1 (c)		<0.072(c)		<0.07 (c)		<0.08 (c)		
In ppb			12.6 (c)		72.8 (c)								
Sb ppb			2.3 (c)		0.81 (c)								
Te ppb			<2 (c)		25 (c)								
I ppm	0.06 (a)												
Cs ppm		0.041 (b)	0.0362(c)	0.05 (a)	0.513 (c)							0.079 (a)	0.060 (a)
Ba		4.93 (b)											
La	0.27 (a)	0.31 (b)	0.31 (a)	0.3 (a)	0.65 (a)	0.18 (a)		0.176 (a)		0.3 (a)		0.41 (a)	0.41 (a)
Ce	0.94 (a)	0.87 (b)	1.4 (a)	1.9 (a)	2.4 (a)	<0.2 (a)		<0.4 (a)		2.1 (a)		0.80 (a)	0.82 (a)
Pr													
Nd		0.82 (b)											
Sm	0.39 (a)	0.47 (b)	0.416 (a)	0.42 (a)	0.82 (a)	0.315 (a)		0.241 (a)		0.4 (a)		0.474 (a)	0.502 (a)

Eu	0.19 (a)	0.23 (b)	0.203 (a)	0.208 (a)	0.354 (a)	0.186 (a)		0.172 (a)		0.221 (a)		0.242 (a)	0.256 (a)
Gd													
Tb	0.14 (a)	0.16 (b)	0.17 (a)	0.16 (a)	0.3 (a)	0.14 (a)		0.116 (a)		0.14 (a)		0.167 (a)	0.172 (a)
Dy	1.05 (a)	1.1 (b)											
Ho	0.19 (a)	0.24 (b)										0.247 (a)	0.230 (a)
Er													
Tm	0.11 (a)	0.089 (b)											
Yb	0.53 (a)	0.57 (b)	0.55 (a)	0.55 (a)	0.93 (a)	0.422 (a)		0.323 (a)		0.5 (a)		0.658 (a)	0.656 (a)
Lu	0.078 (a)	0.083 (b)	0.076 (a)	0.076 (a)	0.14 (a)	0.071 (a)		0.059 (a)		0.079 (a)		0.091 (a)	0.097 (a)
Hf	0.49 (a)	0.53 (b)	0.55 (a)	0.6 (a)	0.89 (a)	0.365 (a)		0.31 (a)		0.43 (a)		0.514 (a)	0.548 (a)
Ta	0.027 (a)			30 (a)	40 (a)	<0.17 (a)		<0.17 (a)		<0.22 (a)		- -	0.041 (a)
W ppb	<250 (a)											110 (a)	170 (a)
Re ppb							0.071 (c)		0.064 (c)		0.09 (c)		
Os ppb							1.79 (c)		2.56 (c)		3.3 (c)		
Ir ppb	3.4 (a)		2.1 (a)	2 (a)		6.7 (a)	1.58 (c)	<5 (a)	2.32 (c)	<4.6 (a)	3.1 (c)	3.6 (a)	3.8 (a)
Au ppb	0.7 (a)		0.42 (c)		0.61 (c)		0.34 (c)		0.21 (c)		0.39 (c)		
Tl ppb			4.9 (c)		4.2 (c)								
Bi ppb			1.5 (c)		3.2 (c)								
Th ppm	<0.06 (a)	0.04 (b)			0.08 (a)	<0.1 (a)		<0.13 (a)		<0.09 (a)	- -	0.044 (a)	
U ppm	0.013 (a)	0.011 (b)	0.0119(c)		0.0243(c)								

*technique a) INAA, b) spark source mass spec., c) RNAA, * calculated*

The initial Sr and Nd isotope ratios differ slightly from those of ALH77005 (Borg *et al.* 1997, 1998).

Becker and Pepin (1993) could not find heavy nitrogen to go along with the rare gasses.

Shock Features

Keller *et al.* (1992) and Treiman *et al.* (1994) found that the shock features in LEW88516 were very similar to those found in ALHA77005. These samples are highly shocked.

Processing

This small (13.2g) achondrite has always been processed on a laminar flow bench. Most of the allocations were done a few months after classification. Some of the allocations were interior, exterior or glass-rich chips (figure XI-7). Most allocations were from a homogenized powder prepared from 1.66 g of interior chips by Lindstrom and Mittlefehldt. Two potted butts were used to produce 11 thin sections (table XI-2).

LEW88516 is listed as a "restricted" sample by the MWG (Score and Lindstrom, 1993, page 5), because of its small size.

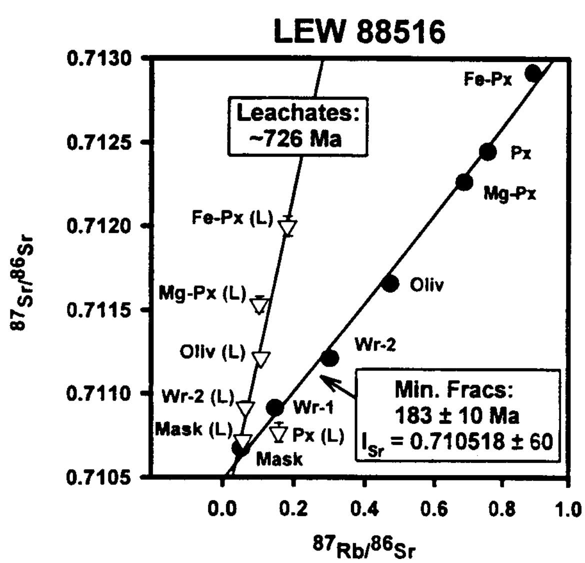

Figure XI-6. *Rb-Sr internal isochron for LEW88516 as determined by Borg et al. (1997).*

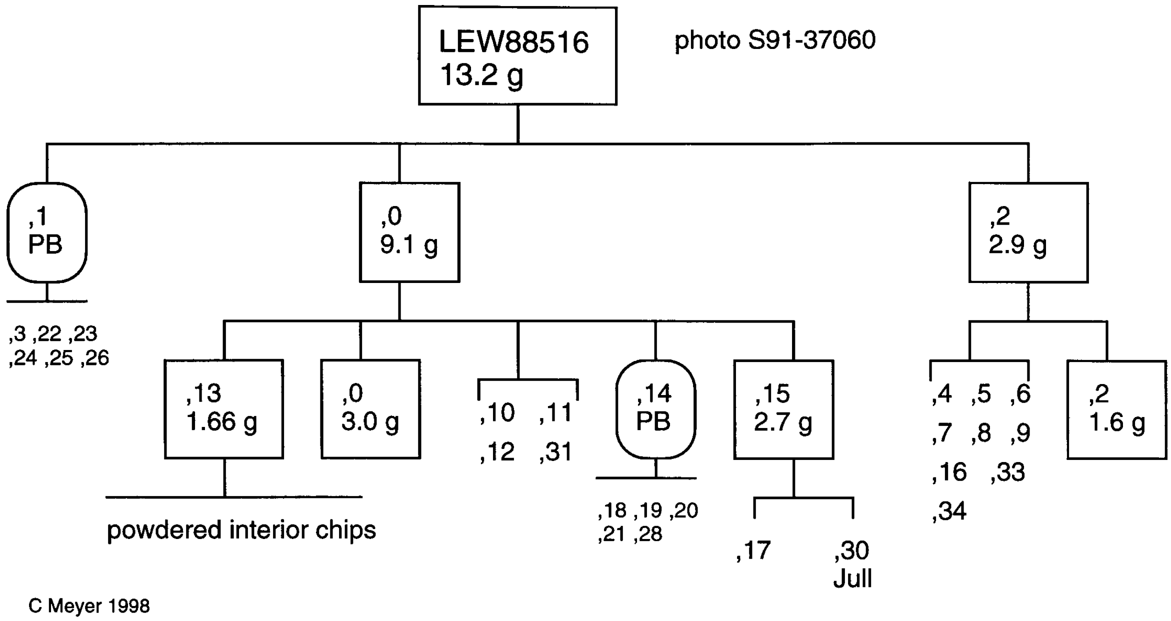

Figure XI-7. Genealogy diagram for LEW88516 for samples allocated up to 1997.

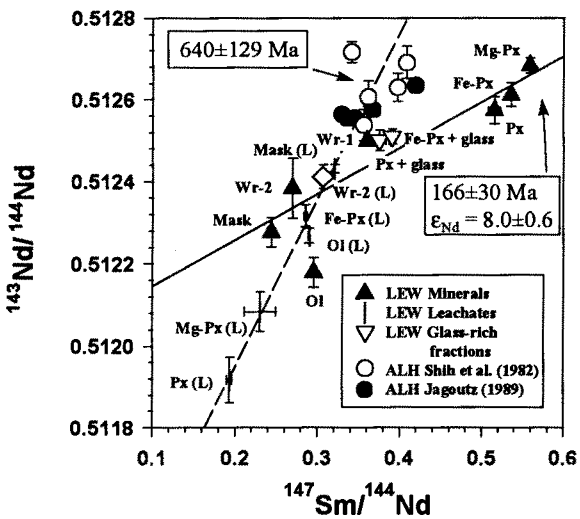

Figure XI-8. Sm-Nd internal isochron diagram as determined by Borg et al. (1998).

Table XI-2. Thin sections of LEW88516.

butt	section	1998	previous	parent
,1				,0
	,3	Mason		
	,22	Papike	McSween	
	,23	Treiman		
	,24	Mikouchi	Prinz, Harvey	
	,25	Warren		
	,26	MCC	Yanai	
,14				,0
	,18	McSween		
	,19	Delaney		
	,20	Palme		
	,21	Boynton		
	,28	Lipschutz		